

A Risk-Management STRATEGY for PCB-Contaminated Sediments

Committee on Remediation of PCB-Contaminated Sediments

Board on Environmental Studies and Toxicology

Division on Life and Earth Studies

National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C.

NATIONAL ACADEMY PRESS 2101 Constitution Ave., N.W. Washington, D.C. 20418

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This project was supported by Grant No. R 827175-01 between the National Academy of Sciences and the U.S. Environmental Protection Agency. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the organizations or agencies that provided support for this project.

International Standard Book Number 0-309-07321-9

Library of Congress Control Number: 2001089191

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National Academy Press
2101 Constitution Ave., NW
Box 285
Washington, DC 20055

800-624-6242
202-334-3313 (in the Washington metropolitan area)
<http://www.nap.edu>

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Printed in the United States of America

include insulation (wool felt, foam rubber, and fiberglass), sound-dampening materials, paints, water-proofing materials, coatings for water pipes and storage tanks, and other materials, many of which have been found in federal buildings or military equipment, such as naval vessels. Although these solid materials might not present a current health risk from PCB exposure, they might become a significant source of PCB exposure as their utility expires.

Another continuing source of PCBs are recycling activities that keep PCBs in circulation for many years. Materials that might contain PCBs include automobile and truck parts (e.g., nonmetallic parts such as glass and plastic), military equipment (e.g., ship parts), plastics, asphalt-roofing materials, and paper.

In most other countries, PCB production is also banned. However, PCBs are reported to be manufactured in Russia and might also be manufactured in North Korea (Carpenter 1998). If that is the case, PCBs might be entering the environment both in those countries and in other countries that buy their PCB-containing products. Although these sources of PCBs are likely to be relatively small, they are a new source of PCBs in the environment. Unfortunately, estimates of continuing worldwide production of PCBs are not available. Such information would improve our understanding of the global balance of PCBs in the environment and the potential long-term impact of site management efforts.

These continuing and new sources of PCBs to the global environment are important to consider as various physical, chemical, and biological processes transport PCBs regionally and globally. This issue is discussed in more detail in the next section.

DISTRIBUTION AND DYNAMICS OF PCBs IN THE ENVIRONMENT

The chemical properties of PCBs, such as stability and low reactivity, made them ideal for many industrial uses. PCBs are slow to biodegrade in the environment in comparison with many other organic chemicals and are generally persistent in all media. PCBs have relatively low water solubility and low vapor pressures (Erickson 1997) that allow them to partition between water and the atmosphere. Once released into the environment, PCBs tend to partition to the more organic components of the environment. For that reason, PCBs adsorb to organic matter in soils and sediments. As a result, PCBs can be found in almost every compartment in the environment (Tanabe 1988).

PCBs adhere to the surfaces of organic particles in the water column, resulting in their eventual deposition and accumulation in sediments. The highest concentrations of PCBs are typically found in fine-grained, organically

rich sediments. Horizontal and vertical variations in PCB concentrations in sediments are common and are dependent on the history of PCB inputs to the ecosystem and on the temporal and spatial deposition patterns of fine- and coarse-grained sediments.

At sites without new inputs of PCBs, the greatest concentrations tend to be found below the surficial sediments, where contaminated sediments are buried by less-contaminated sediments. The distribution of PCBs in sediments is affected by such factors as continuing use and disposal of PCBs; leaching from disposal sites; resuspension by turbulence; redeposition (hydrodynamic forces); chemical changes; and physical and biological mixing of the sediment. The different physical and chemical properties of the individual congeners determine their behavior during those various dynamic processes. As a result, identifying the specific environmental characteristics of PCB-contaminated sediments is challenging. Sediment characterization typically involves a combination of sampling techniques that include direct measurement of PCBs by high-resolution analytical methods and direct and indirect measurement of sediment properties.

PCBs are considered to exist in three phases in the sediment and overlying water: freely dissolved, associated with dissolved organic carbon (DOC),¹ and sorbed to particles.² PCBs sorbed to particles are subject to settling, resuspension, and burial. Particles suspended in the water column are affected by hydrodynamic conditions. PCBs that are freely dissolved or associated with DOC can cross the sediment-water interface and move between the deeper sediments (below the bioturbation or bioactive surface sediment) and the surface sediment. This movement is largely a function of diffusion between the sediment pore water, and the overlying water column. It is dependent on the detailed hydrodynamic structure at the water-sediment interface and can be greatly enhanced by bioturbation caused by organisms living in the sediments. Freely dissolved PCBs in the water column are also subject to volatilization across the air-water interface. Such loss can be substantial, especially in systems that provide substantial time for the water-air interactions.

Transformations of PCBs can also occur in aquatic systems by microbial degradation (in aerobic water columns and surficial sediments), reductive dechlorination (in anaerobic sediments), and metabolism via organisms that

¹The term, "associated with DOC" is used, because the exact mechanism of interaction of PCBs with DOC is not well-defined. DOC can include colloidal materials that are mostly organic matter.

²The term "sorbed" suggests that a combination of adsorptive and absorptive processes are involved, depending upon the types of particles.

take up the PCBs. Metabolism by microorganisms (Mavoungou et al. 1991) and animals (McFarland and Clarke 1989) can cause relative proportions of some congeners to increase while others decrease (Boon and Eijgenraam 1988; Borlakoglu and Walker 1989).

Because the susceptibility of PCBs to degradation and bioaccumulation is congener specific, the composition of PCB congener mixtures that occur in the environment differs substantially from that of the original industrial mixtures released into the environment (Zell and Ballschmiter 1980; Giesy and Kannan 1998; Newman et al. 1998). In addition to environmental transformation products of PCBs, other chemicals, such as polyaromatic hydrocarbons (PAHs), polychlorinated dibenzofurans (PCDFs), polychlorinated dibenzo-*p*-dioxins (PCDDs), pesticides, and metals, might be present in contaminated sediments.

Generally, the less-chlorinated congeners are more water soluble, more volatile, and more likely to biodegrade. Therefore, lower concentrations of these congeners are found in sediments compared with the original concentrations of Aroclors that entered the environment. Higher-chlorinated PCBs are often more resistant to degradation and volatilization and sorb more strongly to particulate matter. Some of these more-chlorinated PCBs tend to bioaccumulate to greater concentrations in tissues of animals than do lower-molecular-weight PCBs. The more-chlorinated PCBs can also biomagnify in food webs (see Box 2-1), and other higher-molecular-weight congeners have specific structures that make them susceptible to metabolism by enzymes once these congeners are taken up by such species as fish, crustacea, birds, and mammals.

The low vapor pressure of PCBs, coupled with air, water, and sediment transport processes, means that they are readily transported from local or regional sites of contamination to remote areas (Risebrough et al. 1968; NRC 1979; Atlas and Giam 1981; Subramanian et al. 1983). PCBs can enter a global biogeochemical cycle that transports them far from their initial source of input. This global biogeochemical cycling of PCBs is the result of volatilization losses from tropical and subtropical waters to the atmosphere. These atmospheric PCBs move from warmer regions to polar regions, especially in the northern hemisphere, where they are deposited to soil and water surfaces (Muir et al. 2000). Table 2-2 presents some atmospheric concentrations of PCBs from various regions of the world, illustrating the scale and variability of their global distribution.

POTENTIAL EXPOSURE PATHWAYS

Humans and wildlife can be exposed to PCBs either directly from contact with contaminated air, sediments, or water or indirectly through the diet.